GOOD PRACTICE CASE STUDY 334

The benefits of including energy efficiency early in the design stage

– Anglia Polytechnic University

- 50% saving in energy consumption
- Annual reduction in CO_2 emissions of 250 tonnes
- Naturally ventilated design based around two atria
- Finalist in ‘Green Building of the Year Award’

GOOD PRACTICE CASE STUDY 334

BEST PRACTICE PROGRAMME
ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

INTRODUCTION

Queens Building, APU

INTRODUCTION

Buildings for further and higher education tend to be energy intensive. Such buildings are intended to provide flexible and functional accommodation catering for a wide range of educational requirements and occupancy patterns.

Energy efficiency measures introduced at the design stage of a new building will ultimately benefit both students and staff. The result will be a comfortable environment conducive to educational needs combined with lower energy costs.

This Case Study outlines the innovative strategy adopted by the management team of Anglia Polytechnic University (APU) for the construction of a new learning resource centre (LRC) - the Queen's Building in Chelmsford, Essex - formally opened in October 1994.

The management team sought to construct a building that reflected the University's commitment to the environment, while still fulfilling its primary purpose. The result is a naturally ventilated construction based around two atria.

The atria not only contribute to energy efficiency, but enhance the appearance and character of this high-profile building. Occupants enjoy the benefits of comfortable temperatures, controlled fresh air and a high level of diffuse natural daylight.

A measure of this achievement is that the Queen's Building was one of three finalists in the 1996 'Green Building of the Year Award'. This annual award is sponsored by the 'Independent on Sunday' newspaper and the Heating and Ventilating Contractors' Association (HVCA). It is supported by, among others, the Building Research Establishment (BRE) and the Royal Institute of British Architects.

The principal features of the building are:

- innovative naturally ventilated design
- low energy running costs
- low maintenance costs
- pleasant internal environment
- cost-effective fast-track design and construction
- energy efficient design features incorporated with no resulting increase in capital cost.

BACKGROUND

Anglia Polytechnic University, formed from the merger of some smaller educational establishments in Cambridgeshire, Norfolk and Essex, was granted university status in 1992. The original Chelmsford campus, in the heart of the town centre, was founded more than 100 years ago to provide adult education for Essex.

From Autumn 1990 to 1995, student numbers have increased by 30%, increasing pressure on the University's existing facilities. In response, in 1992 the University purchased a nine-hectare site on the edge of Chelmsford for a new purpose-built campus. The campus, called Rivermead, will ultimately provide administration, teaching and student residential accommodation.

DESIGN BRIEF

The LRC was the first phase of the Rivermead campus development and was required to provide:

- a library with seating for 700
- a media department
- seminar and study rooms
- offices and catering facilities.

Aware that the campus was to provide facilities well into the next century, the management team decided that the new building should be visionary

DESIGN FEATURES

in its design. A joint strategy group was formed, comprising directors of the development company and the University's senior management team.

The group decided that the key factors in the design were:

- an environmentally conscious building
- high levels of energy efficiency
- low maintenance costs.

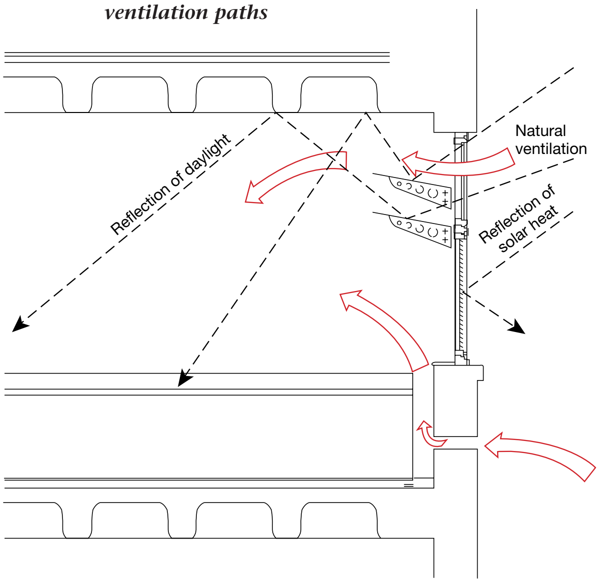
The group also demanded that the use of an environmentally conscious design should not limit the functional performance of the building. Furthermore, as the LRC would be the prominent public gateway for the Rivermead campus it needed to be a high-profile and spacious building.

FAST TRACK DESIGN AND CONSTRUCTION

The LRC was to be designed and built within 21 months, so that it would be fully operational by October 1994, the start of the academic year. It was anticipated that the construction phase would take at least 12 months, placing an onerous timescale on the building's designers.

An innovative design approach was adopted by the chosen designers, ECD Architects. A multi-disciplinary design team, including both architects and engineers, was appointed to undertake an integrated assessment of the energy and environmental impact of each aspect of the building's form and services.

Figure 1 Window section illustrating light and ventilation paths



The design team held a week-long workshop to develop the basic form and environmental strategy for the building. By the end of the workshop, general arrangement drawings had been agreed. In view of the remaining timescale, the University chose to go with a 'design-and-build' construction contract, so that final design development could be completed while the building work took place.

The success of any low-energy building depends heavily on its design detailing, so the design team was transferred from the client to the contractor. This ensured that the design detailing maintained the integrity of the original concept, but still provided the time and cost advantages of design-and-build.

The building was delivered on time, and the total building cost of £4 million was well within budget.

DESIGN FEATURES

Learning resource centres can have particularly large internal heat gains because of the high concentration of students and IT equipment. These internal heat gains can cause the building to become uncomfortably hot in summer, so air-conditioning is usually provided. However, because air-conditioning is associated with high energy costs and adverse environmental implications, the design team decided to avoid using it in the Queen's Building, opting instead for natural ventilation.

The most notable aspect of the Queen's Building design is that overheating in summer has been avoided, without the need for widespread mechanical ventilation or air-conditioning. This has been achieved by:

- adopting a sophisticated natural ventilation strategy incorporating computer-controlled windows, and air movement encouraged by a 'stack effect' within the two atria
- providing an exposed structural thermal mass to absorb transient peaks in heat gain
- minimising heat gains from lighting by using low energy lighting design, and architectural features that improve the availability of natural daylight
- paying close attention to window design.

WINDOWS

Much consideration was given to the window design, the challenge being to enhance the daylight and ventilation advantages of glazing while counteracting the drawbacks of winter heat loss and summer heat gain.

DESIGN FEATURES

The triple-glazed windows have an argon-filled double-glazed unit with a low-emissivity coating on the inner pane. A further single pane of glass is positioned externally, with the intervening gap accommodating a venetian blind, adjustable from within the building. The internal double pane is removable to allow for maintenance of the blind.

Above the fixed vision area is a triple-glazed clerestory window, fitted with a motorised opening mechanism to provide natural ventilation, and controlled by the LRC's building energy management system (BEMS) (see figure 1).

Two internal translucent light shelves, with a mirrored upper surface, project from the upper section of the window. The shelves restrict the glare and any localised overheating of the workstations next to the window, and reflect natural daylight into the depth of the building.

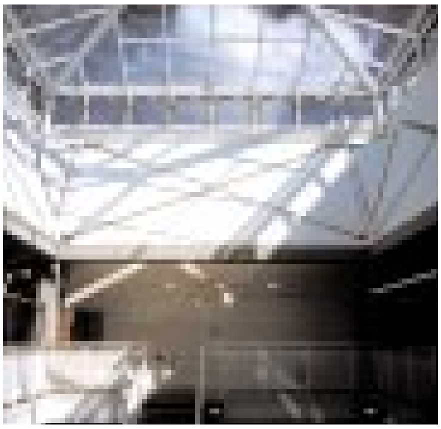
To control solar gain and contribute to the uniformity of natural light, the window areas have been proportionally decreased according to orientation; windows on the south west façade are narrowed by 16% and on the south by 33%.

LIGHTING

The lighting scheme incorporates high-efficiency fluorescent fittings to save electricity and minimise heat generation. The lighting is zoned and controlled on one of four separate schedules.

- Safety lights operate on a time switch when the building is occupied. They are also coupled to the fire alarm system, and will switch on at any time the alarm is activated.
- General and high-occupancy areas are time controlled to operate during the day.
- Intermittently occupied areas are time-controlled and have occupancy sensing to switch off lights.
- Internal perimeter lighting (adjacent to the windows) is time-controlled. There are also photocell controllers to switch off the lights if the internal lighting level exceeds 1000 lux.

The lighting scheme has been designed around a low-level background illumination (150 lux), with low-energy task lights providing additional lighting when required. Great care was taken with the selective positioning of individual light fittings, rather than simply providing uniform background illumination throughout. As a result, while the aisles between book shelving are well lit, no lights have been positioned directly above and behind the shelving where illumination is not required.



Calico sails provide attractive natural light

Daylight reaches the core of the building from the atria. White calico sails have been used at the top of the two atria to attenuate glare and solar gain, and provide an attractive diffuse natural light. Additionally, horizontal fabric light shelves are positioned around their perimeters to reflect subdued daylight deeper into the building.

EXPOSED STRUCTURAL MASS

The use of exposed internal structural mass is an effective way of absorbing excess heat during warm summer days. This stored heat can then be dissipated over night by natural ventilation.

The following structural mass features have been used in the Queen's Building:

- cavity external walls with an exposed 140 mm thermally heavyweight concrete block inner leaf; the blocks use recycled wood chippings as their aggregate (rather than freshly quarried stone) in line with the University's environmental ethos
- exposed coffered ceiling slabs
- concrete slabs located between the timber rafters of the sloping sections of the roof.

Aerial shot of campus

In addition, substantial insulation has been incorporated into the building's walls and roof, external to the thermal mass elements, thus helping to maintain stable and uniform internal temperatures throughout the year.

BUILDING PERFORMANCE

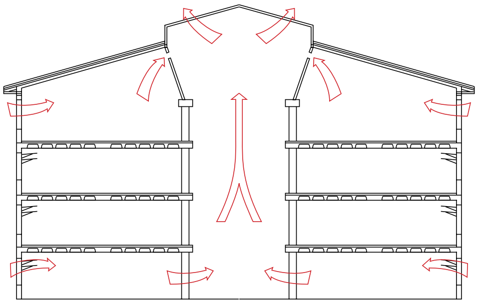


Figure 2 Cross section of building showing atrium and clerestory ventilation

VENTILATION AND COOLING

Background ventilation is supplied naturally by fresh air entering through air-bricks situated at floor level, behind the perimeter heaters that heat incoming air during winter.

Additional ventilation can be provided in response to high occupancy levels (detected by CO_2 sensors) or to provide cooling in response to internal temperature sensors. The increased ventilation is provided by selected atrium and clerestory windows opening automatically (see figure 2).

Rising warm air in the atria creates a stack effect, drawing air into the building through the side clerestory windows. The stack effect creates a maximum draw of air through the lower floors and, to compensate, more windows are opened in the upper floors to equalise the air flows.

Ventilation and cooling arrangements are regulated by the site's BEMS which, as well as sensing internal temperature and carbon dioxide levels, continuously monitors rain, wind speed and wind direction. The wind data is used to determine on which side of the building windows are to be opened, while the detection of rain closes atrium windows and restricts the perimeter clerestory windows to 25% opening.

Natural ventilation is continued overnight in the summer to dissipate any excess heat stored in the building's thermal mass.

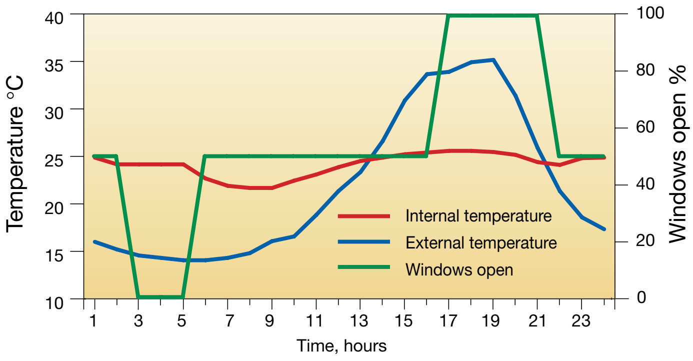


Figure 3 This graph shows that with external air temperatures peaking around 31°C, the exposed structural thermal mass and substantial insulation succeeds in limiting the internal air temperature to 25°C

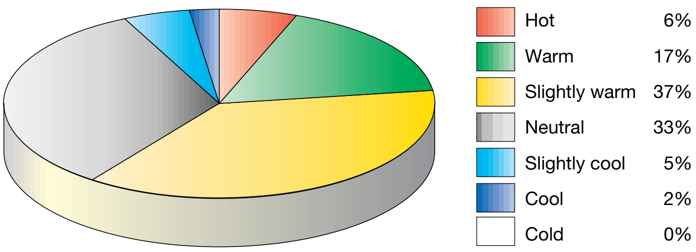


Figure 4 Results of the thermal comfort survey for the period 10-17 June, when the average internal temperature was 24.6°C

BUILDING PERFORMANCE

During its first year of operation, the LRC's total energy consumption equated to 112.3 kWh/m^2, based on an effective floor area of 5700 m^2, with electricity usage being a mere 23.5 kWh/m^2 (21% of total consumption). Overall, this is approximately half the expected consumption of a more conventional design, see Energy Consumption Guide 19, 'Energy efficiency in offices - a technical guide for owners and single tenants' (ECON 19) and represents:

- an annual energy cost saving of £18 000 (at typical 1995 electricity and gas costs)
- an annual reduction in CO_2 emissions of 250 tonnes.

Maintenance costs should also prove to be substantially lower throughout the life of the building, because of the low reliance on mechanical and electrical building services.

The unusually hot summer of 1995 was the first real test of the building's natural ventilation and cooling system. Some initial fine-tuning of the BEMS ventilation control settings was necessary to achieve satisfactory performance, but this had been expected. Daily internal and external temperature profiles are constantly recorded (see figure 3). The thermal performance of the LRC is being monitored by the University's Building Performance Research Unit. Initial results indicate that the building is able to maintain acceptable internal air temperatures, even in very hot weather. A thermal comfort survey of the building's occupants (staff and students) provided encouraging findings. The survey for the period June 10-17th 1995 showed that only 6% considered the building to be 'hot' (figure 4).

FURTHER READING

CONCLUSIONS

Few institutes of higher or further education have adopted such a radical design approach as Anglia Polytechnic University, although many have recognised the benefits that can result from designing for minimum energy consumption.

APU has shown that designing for energy efficiency does not conflict with the functional aspects of a building or detract from the aesthetic and practical qualities of the design and construction. The design, construction and performance should satisfy the original specification.

The project demonstrated that fast-track and design-and-build, with the design team involved in the initial concept and the detailed drawings, can produce a successful, low energy building.

FURTHER READING

Department for Education and Employment. Environmental Responsibility: An agenda for further and higher education. London, DfEE, 1992.

DOE ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

Good Practice Case Studies

333 Energy management at Southwark College - the low-cost practical approach

335 Investment in energy efficiency at the University of Warwick (in press)

336 Monitoring and targeting at the University of Wales, Cardiff

Good Practice Guide

204 Combined heat and power (CHP) in universities

Energy Consumption Guide

19 Energy efficiency in offices - a technical guide for owners and single tenants

The central atrium maximises daylight

The Government's Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

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Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

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General Information: describes concepts and approaches yet to be fully established as good practice.

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